SAWING: Chips are produced by a succession of small cutting edges

a traditional cutting process with multiple cutting point tool;

small teeth (cutting edges) produce chips progressively when passing through a work piece

chips ➔ transported by the space between the teeth ➔ gullets
- the most economical of the basic machining process from the point of view of material/energy wastage (narrow tools)

- more recently - sawing is used to produce a desired shape of pieces (machining)

**CUTTING TOOLS** → **Saw Blades** → three basic configurations

- Hacksaw blade (rigid blade), straight, limited length, teeth on one edge
- Band-saw blade (flexible band – turned around) flexible, long, continuous band
- Circular saw (rigid disk)

Standard nomenclature for a saw blade.
Note how teeth are offset to provide tooth-set to the blade.
Common features: related to all types of tools →

A. Material for blade
B. Tooth form
C. Tooth Spacing
D. Tooth set
E. Blade thickness

A. Material:

→ Small blades
  - high speed steel
  - carbon steel
→ Longer blade
  - combined strips of HSS strips
→ Large size
  - carbide insertions

Method of providing HSS teeth on a softer steel band.
B. Tooth form:
1. Straight tooth
2. Undercut tooth (clear tooth)
3. Skip tooth → for rough cutting

C. Tooth spacing: determines
- size of the teeth
- size of the gullet, the space for chips
- strength of the tooth
- number of teeth engaging with the workpiece

< 1.5 mm → hand saws (0.8 → 1.8)
> 1.5 mm → power hacksaws (1.4 → 6.4)
D. Tooth set:  - advantages for cutting: staggered
   - the kerf is wider than the blade gage thickness →
   - no friction between blade and kerf

E. Blade thickness →
   - hand hachsaw blades - 0.64 mm
   - power hacksaw blade – 1.17 → 2.54 mm

Length of blades →
   - hand hacksaw 10-12 in long ½ in wide
   - power hacksaw 12-24 in long ½ → 2 in wide

As a general rule:
**BLADE: TWICE LONGER THAN THE WORK PIECE**

**SAW BLADES for long band are sold in reels**
- Use combinations of tooth pitch, to reduce noise.

- blade width $\frac{1}{16} \rightarrow \frac{1}{2} \rightarrow$ the minimum radius that can be cut as profile is related to width

- the narrower blades, easier is change of direction
**Circular saw blades** (Cold Saws) – up to 18 in DIA
- large blades use segments or inserted teeth
  (the disk is made of softer material – teeth is tungsten carbide or HSS)

- Teeth segments (several teeth) are fastened by means of screw or rivets → when one tooth is broken – only a segment must be replaced.

Bevelled teeth → each tooth is bevelled each side

Cold saws → conventionally cut, mechanical
Hot saws → friction type disk saws, cutting by melting the metal

Hot band – saw blades – can melt the work at the bottom of the kerf by friction.

Figure 26-20 Left to right: inserted tooth, segmental-tooth, and integral-tooth, and integral-tooth forms of saw constructions.
(Courtesy of Simonds Saw and Steel Company)
SAWING MACHINES

1. Reciprocating saws: (Hack-saws)
   * manual hacksaws – 60-100 strokes/min
   * power hacksaws – are machines with slope feeding
     mechanism consists of:
     - bed
     - frame
     - power mechanism

Low efficiency: cutting in only one direction of the stroke
2. Band sawing machines

**Horizontal metal-cutting band – sawing machines**
- acting similar way as hacksaw
- fed vertically – a feed system
- the stock → bar can be fed automatically after the cut is completed, and clamped for the next cut

Horizontal bandsawing machine
(left) sawing an I-beam;
(right) horizontal bandsaw with machine blade guards removed for blade installation.
2. Band sawing machines
- the ends of the band are welded at two ends

Combinations cut-off & contour machines
- the saw band is very narrow
- the table can be tilted up to 45°
- a welding device for the band and a grinder are provided with the machine
- speed $\rightarrow$ 50 to 2000 ft/min (15-700m/min)
Upright cutoff band sawing

Machines → work help on table
  * blade machine can be tilted 45
  * have power feed & coolant

FIGURE 26-22. Cutting a pipe at a 45° angle on an upright cutoff bandsawing machine. (Courtesy of Armstrong-Blum Mfg. Co.)
Friction band sawing machines
- very high speed 5000 m /min
- hot saw → material cut by friction → high temp at the bottom of the kerf
- good to cut hard materials (hardened steel)
- some ceramics can be cut

Circular blade sawing machine (cold sawing)
- used mainly for cut off of metal
- Small size – simple machines (spindle, disk and table – no power feed )
- power operations – small ones
- power feed – large one (cooling system)
- friction saw disks - up to dia. 6ft, speeds 8000/ min
- abrasive disks can be used too (made by resin and rubber)
SAFETY HAZARD ISSUES
- high speed, easy to break blades
- shield, hand & eyes protection

Power hacksaw with reciprocating blade
-similar kind of metal cutting as in sawing
- Used mainly for surface cleaning and finishing.
  * chips are very small
  * Teeth are much wider
  * Less control of feed → poor control of size

TOOLS: Files
  1. Single cut file: - for hand use mainly, different kinds of cuts and shapes
  2. Band segments for hand filing machines
  3. Disks – for disk filing machine

• Low productive and NO SHAPE CONTROL
Filing machines

- Die filing machines – Reciprocate a file
  - table can be tilted
  - 300-500 strokes/min
  - low productivity

* Disk filing machine
  - grinders – simple but not accurate
  - lower speed than for grinders
• **Band filing machines** – contour band sawing machines used for filing too
  - band segments are used and are led by a groove in the table
  - speeds 50 – 250 ft/min, not accurate

Band file segments (a) are joined together to form a continuous band (b) which runs on a band filing machine (c). (Courtesy of DoALL Co)
BROACHING

Internal/External

(a)  (b)  (c)  (d)  (e)

(a)  (b)
BROACHING

- The machined surface is produced with a single linear stroke of the tool across the surface.

- Finishes entire surface in one pass

- **Broach** - the tool is made of a series of single point cutting edges; every consecutive edge is protruding further from the axis of the broach than the previous one.
- The step (RPT) determines the depth of cut by each tooth (chip thickness)
- NO FEED IS REQUIRED → Simple machines
- the contour of the tool determines the shape of the machined surfaces
- An initial space must be provided in order to pass the tool → a preliminary hole has to be machined

- A very accurate method to get holes – dependent to the broach size

- Spiral motion for the broach can be assumed for production of spiral grooves (helical grooves)

- Very expensive tools (but high productive) – it pays off through the volume of production
- Work is translated past the work with a single stroke of velocity $V$.

- Rise per Tooth (RPT) provides the feed

- Roughing, Semi-finishing, finishing teeth.

Basic shape and nomenclature for a conventional pull (hole) broach. Section A-A shows the cross section of a tooth.
Broaches

Method of reducing the cutting force with large RPT:

• Jump or Motor Teeth.
• Double cut
• Progressive
- Every tooth is a single edge cutting tool, similar to the tooth of a milling cutter.
- Depth of cut 0.025-0.15mm (tooth).

- Rotor Type:
- For rough cuts
- The tooth type called rotor
- Cut is used such that three teeth in series cut only a part of the circumference.
“double - cut” construction of teeth – can be also used

→ here, the teeth are working in pairs

Progressive

FIGURE 26-6 Overlapping successive teeth permits large RPT without increasing the load per tooth.

FIGURE 26-7 Progressive surface broach. (Courtesy of Detroit Broach & Machine Company.)
Extra-wide spacing may be used when chip disposal is a problem. Chip adhering to broach tooth will be displaced by the next chip formed.

FIGURE 26-9 The gullet area provides room for the chips.
1. Pull-type Broach for sizing width and depth of slot in one operation.

2. Push-type 8 point or star-shaped broach.

3. Pull-type single-pass Keyway Broach with threaded type pull end.

4. Pull-type Broach for producing four inverted Keyways.

5. Push-type cut-and-finish Keyway Broach will cut an internal keyway, deburr the keyway, and finish the bore ... all in one pass.

6. Push-type Broach to cut two Keyways 180 degrees apart in one pass. Can also be made in 3 and 4 Keyway style.

7. Push-type "D" Hole Broach. Can also be made in "Double D" style.

8. Push-type Rectangular Broach (shear angle) for sizing rectangular hole, radar wave guide flanges etc.

FIGURE 26-8 Examples of push-and-pull-type broaches. (Courtesy of DuMont Corp.)
- shell broaches → progressive surface broach to machine side & flat surfaces

- the gullet must be large enough to keep the chip inside
An 80-in, long broach constructed from insert is cheaper to build and sharpen in sections.

**Broaching machines (Pullers)**
- speeds less than 15ft/min *hydraulic drive
- a hole can be trimmed in 5-30 sec. 5-50 tones force
- broaches wears out not too fast, life is long
  - vertical (up to 60”) and horizontal (non - limited)
Arbor press used to broach keyway in a gear.

Vertical pull-down broaching machine shown with parts in position ready for the two broaches to be inserted. An extra part is showing lying at the front of the machine.
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Broach materials & design
- usually designed for particular machine
- materials: HSS and alloy steels
- some times – tungsten carbide inserts are used
- shell type → the cutting edges assembled on a arbor

Type of broaching machines
- Push – down (buckling) → pull-up

• Horizontal machines – long broaches and strokes
• Vertical pull-up → many broaches
• Vertical surface broaching machines (to shape surfaces and develop lateral forces)

• Continuous surface broaching – broaches rest and workpieces are pushed through
FIGURE 26-13  (a) Broaching the teeth in a gear segment by horizontal surface broaching in one pass; (b) broach and gear segment.  (Courtesy of Apex Broach and Machine Company.)
FIGURE 26-14  Large horizontal surface broaching machine on left and continuous horizontal, surface broacher on right. (Courtesy of General Electric Company.)